MODIS
Terra Normalized water-leaving radiance
Data Quality Summary

Investigation: MODIS

Data Product: Normalized water-leaving radiance (MOD18)

Data Set: Terra

Data Set Version: 3

Nature of the product

The water-leaving radiance (L_w) is the radiance exiting the sea surface, i.e., solar irradiance backscattered into the atmosphere from beneath the sea surface. The *Normalized* water-leaving radiance (nL_w) is L_w normalized in a manner that removes most of the effects of variations of the solar zenith angle (Gordon and Clark, 1981). This radiance carries information regarding the concentration of marine biota, etc. MODIS provides the top-of-atmosphere radiance data (L_t) that allows estimation of (nL_w) in seven spectral bands (Bands 8 – 14) centered at wavelengths 412, 443, 490, 531, 551, 667, and 678 nm. For typical marine atmospheres and oligotrophic waters (the brightest in the blue), nL_w composes approximately 10% of L_t in the first three bands (412-490 nm), 4% of L_t in the green bands (531 and 551), and ~ 0.4% of L_t in the two red bands. The rest of the radiance is backscattered from the atmosphere and the sea surface. The water-leaving radiance is extracted from L_t through a process referred to as atmospheric correction. Clearly, atmospheric correction is particularly challenging in the green and red portions of the spectrum. In addition, the MODIS calibration requirements are very exacting, e.g., a 1% error in calibration in the blue, green and red spectral regions is equivalent to an approximately 10%, 25%, and 250% in nL_w error, respectively.

The procedure for atmospheric correction is detailed in the (MOD18) ATBD available at http://modarch.gsfc.nasa.gov/MODIS/ATBD/atbd_mod17.pdf. It uses the fact that nL_w is negligible in the near infrared (NIR) bands at 749 and 869 nm (Bands 15 and 16). Thus these bands are used to estimate the atmospheric contribution.

Data Accuracies

The MODIS atmospheric correction algorithm is virtually identical to that used in SeaWiFS processing. Actually the SeaWiFS and MODIS algorithms are the result of a research effort focussed on development of algorithms for MODIS, e.g., see Gordon and Wang (1994) and Gordon (1997). The validation of the SeaWiFS nL_w product is discussed in detail in Hooker and McClain (2000). An updated description of the validation results based on the third reprocessing of the SeaWiFS data set is available at (http://seawifs.gsfc.nasa.gov/SEAWIFS/TECH_REPORTS/PLVol10.tex_typeset.pdf). This report indicates that for the bands at 443 – 555 nm the ratio between of nL_w derived from SeaWiFS to that measured in situ (SeaWiFS:In situ) varied from 0.95 to 1.10 with a standard deviation of ~ 0.25. At 412 nm the ratio was 0.85. The comparison data generally cluster around the 1:1 line; however, at 412 nm at lower values of nL_w the SeaWiFS values tend to be lower than the in situ values. It is important to note that the error in atmospheric correction does not depend on the water properties (as long as nL_w is negligible in the NIR), so as nL_w decreases the *relative* error in nL_w increases.

At the present time (June 2001) detailed nL_w validation data are available only for the MOBY calibration site, so detailed comparisons can only be made for that location. In addition a switch to the "B-side" MODIS electronics restricts the comparison to the time period after October 2000. The results of the comparisons (made by Dennis Clark at NOAA/NESDIS) suggest that for 443 – 551 nm, MODIS and MOBY nL_w's agree to within ~ 20%. At 412 nm the errors are much larger, reaching as much as 60%. There are significant variations in the retrieved nL_w's with scan angle (east-west asymmetry, east higher than west) particularly at 412 (±50 %) and 443 nm (10-15%). At the other wavelengths the cross-scan variation is ~10-20%, but in the opposite direction (west higher). These variations can result from incomplete instrument polarization sensitivity correction, variation of the scan mirror reflectance with angle of incidence, etc.

Cautions When Using Data

The MODIS-retrieved nL_w's are expected to improve with time. For the data accuracies described above, corrections to address several known problems will not be included in the processing until Version 3 of the MODIS ocean suite is released. For example, there is a clear variation in the sensitivity of the individual detectors in each MODIS spectral band (recall MODIS scans ten lines simultaneously with ten detectors for each spectral bands), and this has not been removed in this analysis. The variation of the sensor's response with scan angle only includes pre-launch corrections, both with respect to mirror side and cross-scan correction. Both of these effects lead to noticeable banding in the nL_w fields. The corrections for the measured MODIS polarization sensitivity are being assessed. The polarization sensitivity is a strong function of the scan angle, so separating polarization and sensor response-versus-scan-angle effects will be particularly difficult.

Expected Revisions

The revisions in the processing code will mainly reflect improvements in the on-orbit characterization of MODIS. In particular, as more validation data become available, they will provide better understanding of the MODIS response-versus-scan-angle effects, detector-to-detector sensitivity variation, and the MODIS polarization-sensitivity correction. As this understanding leads to improvement of the processing, this document will be updated to reflect the expected data accuracies.

Quality Assurances

There are four levels of quality for the nL_w's. These are based on the values of certain flags related to atmospheric correction (http://modis-ocean.gsfc.nasa.gov/qa/). There are two kinds of flags – Common flags and Product Specific flags. Most of the Product flags are for diagnostic purposes, others reflect some failure of the processing.

In the common flag, bits are set as follows:

Bit 1 – Pixel not processed
Bit 2 – Atmospheric correction failed
Bit 3 – Satellite zenith angle > 55 Deg.
Bit 4 – Solar zenith angle > 70 Deg.
Bit 5 – Shallow water
Bit 6 – Sun glint (predicted reflectance > threshold) or Cloud
Bit 7 – Invalid or missing ancillary data
Bit 8 – Land

In the product specific flag that includes nL_w, flag bits are set as follows:

Bit 1 – Contribution from molecular scattering could not be computed.
Bit 2 – nL_w(551) too low (< Threshold)
Bit 3 – Bright water – Coccolithophores detected (Brown and Yoder [1994] test)
Bit 4 – (Not related to nL_w)
Bit 5 – Aerosol contribution too large (AOD at 865 nm > Threshold)
Bit 6 – (Not related to nL_w)
Bit 7 – (Not related to nL_w)
Bit 8 – Absorbing aerosol (not implemented)
Bit 9 – Cloud (Albedo > Threshold)
Bit 10 – One or more bands missing.
Bit 11 – Any $nL_w < 0$. (Bands 8-14)
Bit 12 – Any invalid L_t value (e.g., saturated)
Bit 13 – Not used
Bit 14 – Aerosol correction failed.
Bit 15 – ε(749,869) out of range.
Bit 16 – Aerosol contribution (L_t–L_r) < 0 in Bands 15 and 16

The quality levels range from 0—3 according to the setting of various flags above. Quality Level 0 indicates no known problems, Quality Level 3 indicates that the data are unusable. The Quality Levels are related to the Common and Product flags as follows:

Quality Level 0: No Common or Product flag bits set.
Quality Level 1: Common flag bit 3 (Satellite Zenith Angle > 45 Deg.) set
Quality Level 2: Common flag bit 6 (Sun Glint above threshold) set.
Quality Level 3: Common flag bit 2 (Failed Atmospheric Correction) or bit 8 (Land) set, or Product flag bits 10, 11, 12 (Impossible nL_w) set.

References

C.W. Brown and J.A. Yoder, Coccolithophorid blooms in the global ocean, *J. Geophys. Res.*, **99C**, 7467—7482, 1994.

H.R. Gordon, Atmospheric Correction of Ocean Color Imagery in the Earth Observing System Era, *Jour. Geophys. Res.*, **102D**, 17081-17106 (1997).

H.R. Gordon and D.K. Clark, Clear water radiances for atmospheric correction of Coastal Zone Color Scanner imagery, *Applied Optics*, **20**, 4175-4180 (1981).

H.R. Gordon and M. Wang, Retrieval of water-leaving radiance and aerosol optical thickness over the oceans with SeaWiFS: A preliminary algorithm, *Applied Optics*, **33**, 443-452 (1994).

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